SIMPLIFIED MODELS FOR PASSIVE SAFETY ENGINEERING

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ABSTRACT

In order to reduce delays of development of new vehicles, PSA has been using since 1998 a strategy based on sharing conception into several and hierarchical steps (V cycle). At the very beginning of a project, when only a few information are known, classical (and complex) FE models are replaced by simplified models, composed of sets of springs and loads elements containing properties (flexion, compression, shear) equivalent to complex FE pieces.
Up to now, these simplified models are created using FE models of vehicle with approximately same architecture. Sets of spring elements and properties are adjusted in order to reproduce FE model behaviour. When simplified models behaviour is judged representative of the physics, they can be used for conducting many investigations not only for studying a wide range of design parameters but also for evaluating the robustness of a specific design. The results permit to write technical specifications, for design departments, which in fact build the car pieces.
Using simplified models reduces delays of building numerical models (by a factor of five) and divides by 100 solving delays. It makes easier modelling modifications (a day instead of a week).
Finally, simplified models improve efficiency of crash simulation engineers by diminishing modelling time, by increasing the numbers of iterations and permitting a better understanding of the physics.
In the future, the aim of this method is to build simplified and classical FE models by using directly the CAD parts with additional physical properties in order to dispose automatically of a model which complexity depends on the available CAD data.

INTRODUCTION

The numerical methods for testing crashworthiness have been used in vehicle development since 1990. PSA currently uses RADIOSS software for this purpose and has developed its own pre-post processor for a better adaptation to mechanical engineers and car design.

The vehicle development based on sharing conception into several and hierarchical steps, has shown very rapidly that classical F.E. models are not adapted to early stages because of their complexity and their slowness.
For this purpose, adaptations of RADIOSS software and PSA pre/post-processor have been conducted in order to manage simpler models but still representative of the physics and which CPU performance is compatible with a lot of iterations in a short time.
This approach is intermediate between complex F.E. models (200K nodes), one-dimensional spring, and lumped mass models.
The technique used for their creation is to replace car body by using springs (for longitudinal behaviour) and coarser panel meshes which mechanical comportment is equivalent.
The originality of this approach is not in the intermediate model itself but in the way it has been implemented in the PSA pre-processor. The car model is divided into sub-systems, consisting of either FE. parts or equivalent parts depending on the type of data the user currently knows.
At the very beginning, the car model consists only of equivalent parts (springs and panels) it allows to:

- Test a wide range of design parameters
- Establish the energy balance of the crash
- Give technical specifications to organic parts

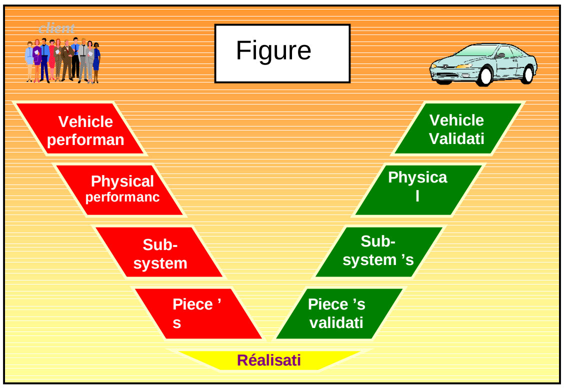
As output of these models, technical specifications are used for drawing physical pieces. Then, it is possible to switch progressively between simplified parts and refined F.E. ones. It can be considered as a first step to continuous engineering from CAD drawings to complex simulation models.
Well adapted to frontal crashes, these models are currently developed for lateral and rear crashes.

CONTEXTE

The development of new car can be visualised in 2 different manners:

- Chronological planning of studies which specifies the task timing
- Hierarchical steps defining for a specific task the way of working.

At PSA, the hierarchical approach is based on the V-cycle (figure 1).



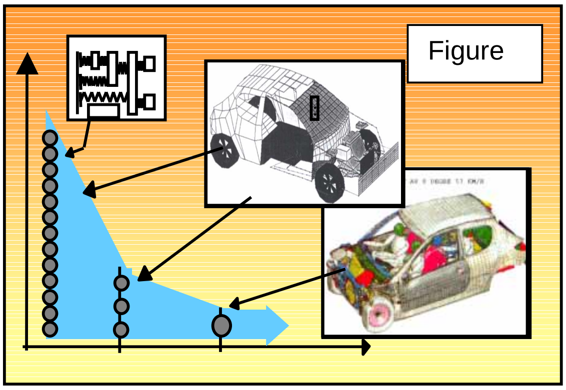
Starting from the client needs (*I want the best car for passive safety*):

- The first step permits to translate these clients' desires into an automotive engineer language. This allows to specify car performances (*good protection at 180 km/h…*) and criteria adopted for measuring this protection (*HIC < 1 for every crash configuration, intrusions in the car < 0,2 mm…)*
- The second step delivers some generic technical specifications (*mainly the crash chronological events and some functional specifications on the body and the mechanics)*
- The third step delivers more detailed specification which permit drawing of pieces (*for a longitudinal is there any section which responds to the above specification)*
- The fourth step takes into account every constraint (mass, process, cost) on pieces in order to deliver the final specification before the realisation of a prototype.

When arrived to this point, the prototype realisation of a specific piece is possible and the V-cycle can be run top ward, step by step, in order to validate first parts, then sub-systems and finally the whole vehicle.

Because of chronological planning are shorter and shorter, the left branch of the V-cycle is dedicated to numerical studies as the right branch consists of a mix of experimental and numerical studies on sub-systems or complete vehicle.

Very rapidly the problem arises that for step 1 to 3, classical FE. models were too much complex (in fact the lifetime of some pieces is shorter than the delay of CAD drawing, meshing, calculating…).
For these steps, the main goals are to get very fast answers on the feasibility of different architectural solutions (see figure 2): Efficient models have to be refined enough to qualify or disqualify these architectural possibilities but sufficiently coarse for reactivity reasons. Figure 2 shows an ideal situation where the complexity of models is reversed to the number of solutions to be tested.



In this ideal case the finite element model is used in order to verify and optimize the final architecture.

It can be seen also on figure 2, that at the very beginning of a vehicle development, simple spring-mass models can be used as indicators. These models are able to evaluate the way the crash energy is dissipated inside the vehicle.
Unfortunately these models do not permit to draw parts of the vehicle since the spring stiffness do not take into account architecture parameters (3D behaviour, geometrical constraints etc.)
For a better representativity of vehicle comportment the model should be composed of elements whose behaviour is 3D as in reality and whose characteristics can be used for drawing pieces. This is the challenge of simplified (or intermediate) model.

CREATION OF SIMPLIFIED MODELS

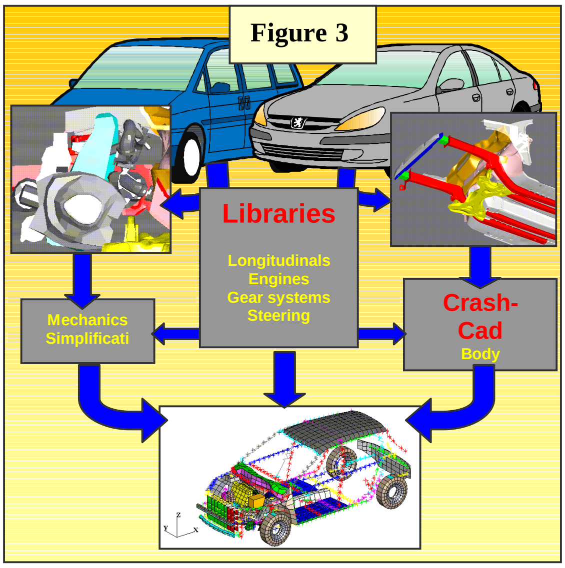
Creation of a simplified model is depending on the way it will be used. As told before the main goals of these models are the followings:

- Classification of architectural solutions in term of crash performance
- Functional specifications on sub-systems

The first goal requires that the models are able to discriminate the tested solutions (by mean of energy balance, body force-displacement behaviour and kinematics). For this, the models have to be composed of every part having a role in the crash scenario.
The second goal supposes that the input of physical parameter is constrained by some drawing considerations. Even if CAD is not present, the parameters have to be estimated in a realistic way and have to be coherent. For example when designing a longitudinal for compression, flexion and shearing parameters have also to be coherent and derive from existing or virtual but realistic longitudinal.

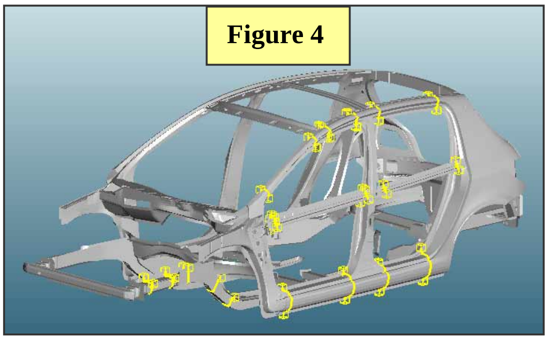
__Global scheme__

These considerations give the scheme of the model creation, which is resumed on figure 3.



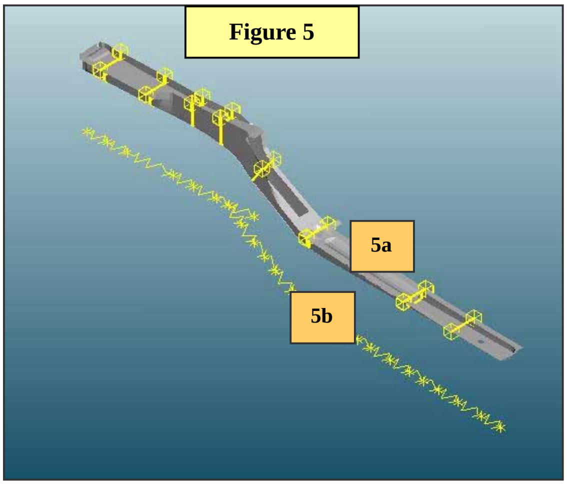
Starting from existing vehicles (old F.E. models) and existing part libraries, the user is able to build any simplified model:

- Engine and gear systems are simplified directly in the pre-processor. These parts are managed as rigid bodies or articulated bodies in the intermediate models and can be adapted very easily to any vehicle.
- Special treatment is made on the body by using CRASH-CAD software for characterisation of longitudinals (see figure 4). This software allows obtaining mechanical parameters of any longitudinal by entering the section geometry, thickness and material properties.



__Example of longitudinal characterisation__

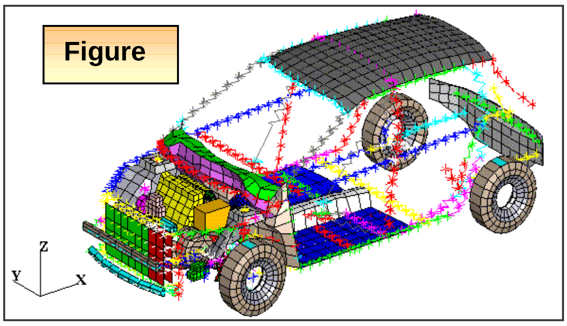
Each longitudinal of a vehicle is characterised by one or several geometrical sections. A special sketcher permits to inform CRASH-CAD on the section geometry and the pre-processor is able to order and complete the data (thickness and materials) in order to constitute the whole longitudinal (figure 5a: location of sections of F.E. model).



CRASH-CAD calculation is performed automatically and finally the pre-processor builds by itself the simplified model of the longitudinal by creating series of connected springs (figure 5b). Spring characteristics are derived from CRASH-CAD calculations.
Knowing the theory of longitudinal collapsibility, this kind of model rises the following problem: when collapsing any longitudinal shows on the force-displacement diagram, first a peak then a plate. By using this physical behaviour in the simplified model, each spring shows the peak, which is not the case in the reality. This problem has been solved in the simplified model behaviour.

Another difficulty is to simulate the panels constituting the vehicle (windscreen, floor etc.). Researches at PSA have been conducted in order to find equivalent comportment between refined meshes and coarse meshes (the mesh size is much larger in the simplified model and is approximately 100mm).

The result is shown on figure 6. It takes between 1 to 3 weeks to build such a model depending on the starting data.



The model is constituted of about 20 K nodes and 14 K shell and spring elements (compared to the 200 K elements of F. E. model).

MODEL PERFORMANCE

When dealing with simulations it can be distinguished two types of performances: CPU performance and physical representativeness.

Computer performance

First in term of CPU time, the simplified models are much faster than F.E. models. The CPU performance results in the following:

- Less elements and nodes (about ten times)
- Time step which governs the CPU time and the model stability (about 1 µs in the F. E. model) can be increased up to 10 µs

This CPU performance allows testing many solutions per day and using this kind of model in optimisation procedures or experimental plans.

Physical representativeness

The second point and the most important is the physical performance. Before using this kind of models for car developments, several validations have been made on existing vehicles.
In this paper, only frontal configurations will be presented.
The validation procedures have been made mainly using the 0° rigid wall procedure and EEVC deformable barrier procedure (of course, a simplified model of EEVC deformable barrier had to be developed prior using the intermediate model in this crash configuration)
The checked output data are classical ones:

- Global deformation of the vehicle
- Chronology of events
- Force-time diagrams in main longitudinals
- Kinematics of vehicle compartment

Global deformation and chronology

It can be seen on figure 7 that both models (simplified model coloured in grey, F.E. model in green) show the same deformations in frontal impact on rigid wall.

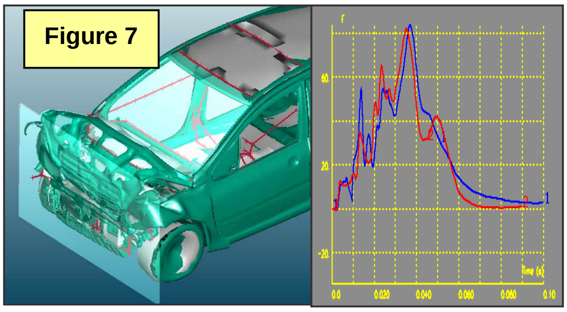


Figure 7

The chronology of events is quite comparable. The force vs. time diagram on the rigid wall shows good correlation between F.E. model (in blue) and Intermediate model (in red), the main events are also respected. For example stopping of engine is quite well predicted by the intermediate model (in red on figure 8).

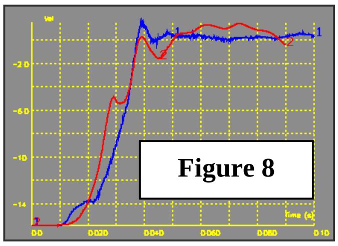


Figure 8

Force vs. time diagrams

Figure 9 shows the comparison on the front rail at different locations.

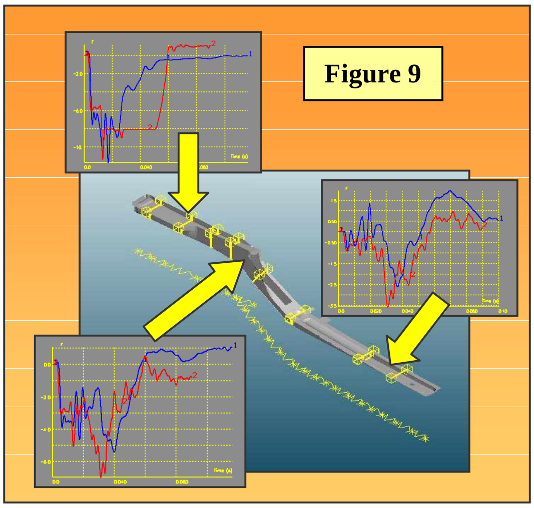


Figure 9

As seen on the figure, the correlation is sufficient to perform iterations on the behaviour of such longitudinal and compare different functional solutions without any specific CAD drawing.

This is also true for sub-frame fixations (figure 10)

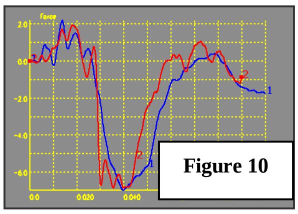


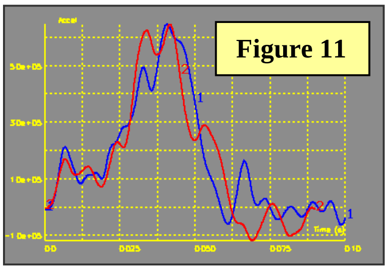
Figure 10

In this case, it is very easy to give specifications on sub-frame minimum stiffness.

Kinematics

Cinematic variables are useful when dealing with occupant behaviour. It is important for the intermediate model to give good approximation of the central pillar acceleration or passenger compartment intrusions.

Figure 11 shows the central pillar acceleration of both models.



This acceleration curve can be entered in occupant safety evaluation models, in order to get early specification on restraint systems.
The intermediate model permits also to give an approximation of intrusions inside the occupant compartment. Unfortunately because of coarser meshes (mesh size about 100 mm) in the floor model, the simplified model gives only an average value. Nevertheless, for this specific point, intrusion results can be used in a relative way in order to classify solutions.

CONCLUSION

Although the results shown in this paper concerns only the rigid wall configurations, the same demonstration should have been done on EEVC offset barrier crash configuration. The simplified model gives also in this case good result.
The representativeness of intermediate models is sufficient to use these models for vehicle design. At the moment, they permit to give early specification for longitudinal stiffness and for crash events on frontal crash situations. They are going to be extended in a narrow future for side and rear crash.
Future developments are also envisaged in order to improve their efficiency:

- Extension of element or part libraries and pre-processor ergonomics in order to facilitate the model preparation.
- Improvement of relationship between longitudinal and panels (for example: right now, rear rails are connected on the floor panel in a very simple way). These amelioration's should be used also for mixed models (simplified models with complete F.E. parts)

This kind of model is well adapted to the vehicle developments at PSA since the resulting specifications are currently used for designing actual pieces and permit to optimise very early the vehicle comportment.

Thanks to their CPU performance, optimisation procedures are very efficient with these models, this is not the case with classical F.E. model whose complexity and poor reaction time avoid (up to now) the optimisation approach.

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